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The author Cousin to her Father

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A
TREATISE
OF
Artificial Magnets;

In which is ſhewn
An eaſy and expeditious METHOD
of making them,
Superior to the beſt *Natural* Ones:

AND ALSO,
A Way of improving the *Natural* Ones,
and of changing or converting their POLES.

Directions are likewiſe given
For making the *Mariner*'s *Needles* in the beſt Form,
and for touching them moſt advantageouſly, *&c.*

By J. MICHELL, B. A.
Fellow of *Queen*'s College, *Cambridge.*

The SECOND EDITION, corrected and improved.

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A TREATISE of

Artificial Magnets.

INTRODUCTION.

THE deſign of the following pages is to communicate to the Publick a very eaſy and expeditious way of making Artificial Magnets.

The Advantage, that muſt ariſe to Mankind in general, but particularly to Seamen, from having a Method of procuring † Magnets much ſuperior to the beſt natural ones at a very trifling expence, will ſufficiently juſtify the publication of this treatiſe, with reſpect to the *Matter* contained in it: and as to the *Manner* and *Form* of it; theſe I muſt leave entirely to the candour and courteſy of the Reader.

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† Perhaps ſome may imagine, that though the Artificial Magnets may be ſuperior to the others in *Strength*, &c. yet poſſibly there may be ſome difference in the *Direction* of ſuch Needles as are touched by them, and of thoſe touched by Natural Magnets: but different Magnets, of any kind whatſoever, never make the leaſt difference in the Needles they touch, except in the degree of *Strength* which they communicate; this is a fact well known to all who are acquainted with the nature of Magnetiſm.

I propoſed at firſt to publiſh, with this Method of making Magnets, a Theory alſo of Magnetiſm, which I endeavoured to eſtabliſh by Experiments; to which I added others of a miſcellaneous nature, ſuch as appeared to me moſt uſeful and entertaining, amongſt thoſe I had either made myſelf, or collected from the labours of others: but finding that this would ſwell theſe ſheets to too great a bulk, I choſe to defer that part till ſome other opportunity; eſpecially when I conſidered, that any Philoſophical Inquiries into the Laws and Nature of Magnetiſm, would be of very little uſe or entertainment to many of the Artificers and Seamen, for whom principally I intended this part.

I have endeavoured every where to make myſelf as intelligible as poſſible, and have omitted nothing, that appeared likely to prevent any miſtakes. This may make ſome things perhaps ſeem tedious, or unneceſſarily repeated; but if any perſon thinks ſo, I muſt beg him to conſider, that all people are not equally ready at comprehending deſcriptions of things, they were not before acquainted with; and that therefore he ought to bear a little with what to him may ſeem unneceſſary, for the ſake of others leſs acute and ingenious than himſelf.

The Reader will meet with ſome few directions for making Needles in the moſt advantageous manner; for touching them properly; *&c.* together with ſome uſes of Magnets either not commonly known, or at leaſt not much attended to by the generality.

In the method of making Artificial Magnets, another Magnet is made uſe of, in order to obtain ſome degree of power to begin with; but that no one may be at a loſs in caſe he ſhould want to make them, where no other is to be had, there is a method propoſed towards the end, of obtaining Magnetiſm by means of three Iron bars.

As it is neceſſary, that all ſingle unarmed bars, intended to be made Magnets, ſhould have a ſufficient length in proportion to their weight; (for otherwiſe they will not attain to near ſo much perfection;) there is therefore ſubjoined a table of ſuch lengths as are proper for bars of different weights. Beſides the plain ſtrait bars, which are the moſt proper for common uſes, there are a few other forms propoſed, ſuch as ſeemed moſt likely to be farther convenient and uſeful upon different occaſions. To the whole are added directions for improving *natural* Magnets, for changing, and converting their Poles, and for making both ſingle and compound armed *artificial* ones in imitation of them.

It may not be amiſs to mention ſome of the Advantages, that the Artificial Magnets have over the Natural ones, and to ſay a little in favour of the Method here offered to the Publick for making them, which is probably capable of bringing them to the greateſt perfection, the nature of the materials, they are made of, will admit.

The Advantages then of Artificial Magnets are,

Firſt, That they may be had at very little more expence and trouble, than the prime coſt of the Steel they are made of, and the labour of forging them into bars of a proper ſize and ſhape; whereas Natural Magnets (ſuch as are good at leaſt,) are very expenſive; and if armed, there muſt be a great deal of labour beſtowed on them in grinding the Poles, fitting on their Armour, *&c.*

Secondly, They may be had plentifully enough to ſupply every body; but Natural Magnets, that are good for any thing, cannot be procured at all, except in ſmall quantities.

Thirdly, They are greatly ſuperior to Natural Magnets in Strength, and perhaps better able to communicate the Magnetic Virtue in proportion to their Strength. Few of the Natural Magnets are able to touch well à Needle that is hard, unleſs it be very ſmall; but good Artificial ones will do it very eaſily. From this * inability of the generality of Natural Magnets to touch large needles when hard, it has been the uſual practice to reduce almoſt all Mariner's needles to a ſpring temper, that they might be able to receive a ſufficient Strength from their touch, which otherwiſe they would not do.

Perhaps ſome may be apt to imagine, becauſe the Natural Magnets, which are armed, (as moſt of them are,) lift ſometimes a great deal more than ſingle Artificial Magnets, that therefore they are better; but this will be eaſily diſproved by experience. The reaſon, why they ſhew ſo much to advantage, is becauſe they will lift vaſtly more in proportion by both Poles, than by one; and this alſo the Artificial compound Magnets will do; and they will beſides lift much more than the Natural ones of the ſame Size. The following inſtance may ſerve to ſhew the difference between the Artificial (ſingle) Magnets and the Natural ones: I have a Natural Magnet, which weighs ſix Ounces and half with its armour, and which is able to lift by both Poles ten Ounces, that will not touch a piece of Steel ſo well, as a good Artificial ſingle one, weighing only an eighth or tenth part of an Ounce.

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* It is this weakneſs of the Natural Magnets, that has led ſeveral into the error, that ſpring-tempered Steel will receive the greateſt Power; whereas it only receives the Magnetic Virtue with *more Eaſe*, but will not *retain* ſo much of it.

A good Artificial Magnet of about two Ounces weight, ſix Inches long, will touch as large and as hard a Needle, as *moſt* of the beſt Natural Magnets in uſe, and perhaps as *any*.

Fourthly, The Eaſe, with which Artificial Magnets are reſtored to their former Strength, in caſe they are at any time damaged, gives them a great Advantage over the Natural ones; which are nearly, if not altogether as liable to be impaired, as the former, and cannot be reſtored but by the aſſiſtance of them, or by Natural ones greatly ſuperior to themſelves.

Fifthly, In the Artificial Magnets we can have ſeveral Poles; as for inſtance, in a long bar we can have a North Pole at each end, and a South Pole in the middle, or two or three South Poles, and as many North Poles, alternately, *&c.* This is what cannot be had in the Natural Magnets, but by chance, and in a ſmall degree; and though this may be no great advantage for the common purpoſes of Magnets, yet it may be of uſe to thoſe, who would try Experiments.

Sixthly, The Artificial Magnets have many Advantages on the account of their being made in any Form. The Natural Magnets are much too ſhort, in proportion to their bulk, and conſequently cannot attain to that perfection, which they otherwiſe might do. Some of them are ſo very deficient in length, that probably, if they were ſlit into a hundred pieces, of the whole length of the ſtone, and properly made magnetical, they would make a hundred Magnets, each better than the whole ſtone was before.

Another Advantage of Shape is, that the two Poles of an Artificial Magnet, of any Size, may be brought as near each other, as any one pleaſes, and yet the Magnet have a ſufficient length in proportion to its bulk; as in the Annular and Horſe-ſhoe Magnets hereafter deſcribed.

The Convenience, with which the Artificial Magnets (on account of their being long and ſlender in compariſon of the others,) may be applied in the manner of the *double Touch* (hereafter deſcribed) is another Advantage ariſing from their Shape: And this is a great Advantage indeed; ſince by this means half an Ounce of Artificial Magnets may eaſily be made to touch a much larger bar, than the beſt Natural Magnet in the known world. The Natural Magnets too may indeed be applied after the manner of the *double Touch*, and with conſiderable Advantage, but vaſtly leſs however than the others; with which it is as practicable to communicate the Magnetic Virtue to a bar of Steel of a Ton weight, as to one of an Ounce, and that with a ſmall quantity of them, perhaps two hundred weight, or leſs: whereas it would be impoſſible to do it with leſs than ſome thouſand Tons of Natural Magnets, and thoſe not leſs than ſome hundred Tons weight each.

This may ſuffice to convince every impartial Perſon of the great Advantage of Artificial Magnets.

It may perhaps be expected, that, as Dr. *Knight*, (who firſt brought the Artificial Magnets to their preſent known perfection,) and perhaps ſome others have made Artificial Magnets, as well as myſelf, ſomething ſhould be ſaid of their Method, compared with what is here offered to the Publick. Whether their's is the ſame as this, I know not; but it is highly probable, that this is equal to their's, or any other that is already, or may be hereafter found out. This ought not however to deter any one from attempting farther improvements; for how probable ſoever it may ſeem at preſent, that the method here propoſed is as good, as any can be, it is nevertheleſs but *probable.*

I have compared ſeveral Magnets, made after the Method here propoſed, with thoſe I have ſeen of Dr. *Knight*'s, and have found ſome of them greatly ſuperior to what thoſe of his were, when I ſaw them; and conſiderably ſuperior to what his were ſaid to have been at firſt, when they came out of his hands. I have had, amongſt thoſe I have made, three or four, (the heavieſt of them weighing about an Ounce and three quarters,) that have lifted, when freſh made, from eighteen to twenty Ounces each, and have all continued to lift better than ſeventeen. Theſe indeed were all pointed at the lifting end, which will make them lift perhaps an Ounce or ſome ſuch matter more, than they would otherwiſe do: but they were alſo conſiderably lighter, than thoſe, with which they were compared, (which were five Inches and half long,) and were reckoned to lift at firſt only fifteen or ſixteen Ounces; but which, when I ſaw them, would not lift near ſo much as that, probably, for want of proper precaution in keeping them. †

I have heard of * Magnets of about two Ounces weight, that have lifted ſeven or eight and twenty Ounces. This was owing, I ſuppoſe, to ſome difference of form, or ſome other circumſtances in the Iron lifted: for on trying, ſince, one of the three or four Magnets mentioned above, I found it, juſt after it was retouched, to lift an Iron Poker, weighing two and twenty Ounces, with great eaſe; which it ſtill continued to lift ſeveral days after, though with ſome difficulty. The reaſon why this lifted more than formerly, I apprehend, was owing to the difference of the Shape of the Poker, from the bar it uſed to lift; which difference conſiſted in a pretty large knob at the top, that was broad, and ſomewhat flatted. But from what I have experienced ſince, I do not find any ſhaped bar better to be lifted, than a plain ſquare one, of a moderate length in proportion to its thickneſs, with a plain poliſhed ſurface at one end, which may be reduced to about one third of the whole ſize of the bar, by taking off the corners and edges.

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† From what has been here ſaid, I do not mean to infer the ſuperiority of this Method above the Doctor's, but only an equality with his; the difference here mentioned being owing, in all likelihood, to the want of proper care in the *hardening* of the Steel bars, that his were made of; which is a moſt material Circumſtance: for the ſame bar, that, when properly hardened, may be made to lift twenty Ounces; when greatly over or greatly under-heated, will not lift above ſix at the utmoſt.

* Since the Publication of the firſt Edition of this Treatiſe, I have ſeen ſome of theſe Magnets, and found them, upon tryal, to be of the ſame Strength with that which lifted the two and twenty Ounces mentioned in this paragraph; and I have now got one of the ſame Size, which will lift about three Ounces more.

As the Method for making artificial Magnets, here offered to the Publick, is not, as far as I have hitherto found, inferior to any known; ſo it is probably capable of bringing them to the greateſt perfection, the nature of the Materials, they are made of, will admit; and this, becauſe a bar of Steel will not retain ſo great a degree of Virtue as may eaſily be communicated to it; but whether it be much or little, beyond its due quantity, that any bar receives, it will loſe what is above that quantity immediately; unleſs by ſome means or other it is preſerved in that more ſtrongly Magnetical State. This will appear very probable, from the *Method* of making Magnets; but, by the following *Experiments*, it will be put out of Doubt.

EXPERIMENT I.

I took two ſemicircular Magnets, of the ſame ſize, each about two Ounces weight; and placing them with their ends together, ſo that they compleated the circle, I made them Magnetical according to the directions hereafter given; then trying to ſeparate them immediately, I found, that not leſs than ſix or ſeven pound was ſufficient to do it; but that, after they had been once ſeparated, they might be ſeparated again by three or four pound.

EXPERIMENT II.

Another Experiment, almoſt the ſame with the former, was thus. I made Magnetical a ſmall ſingle bar armed, keeping an Iron wedge applied to it during the operation; I then tried what it would lift, and found that it lifted full one fifth part more, by the wedge, before it had been once ſeparated, than after.

From hence it appears pretty evident, that it is not owing to any defect in the *Means* of making the bars Magnetical, that we cannot communicate a much greater degree of power to them, than that they will remain at; but rather to the *Inability* of the Materials, they are made of, to retain any more. If two Magnets be placed with their Poles of the ſame denomination together, they will damage each other conſiderably: and if ſeveral be ſo placed, ſome of them ſhall not only be quite ſpoiled, but perhaps even have their Poles converted. Hence it is plain, if we conceive any Magnet, as divided into ſeveral, by Sections parallel to its Axis, that each of theſe will be endeavouring to damage all the reſt. Now, if we ſuppoſe, that the hardneſs of the Steel is able to reſiſt this Endeavour, in ſome meaſure; this will very well account for any piece of Steel retaining its Magnetiſm to a certain degree, and for its not retaining any more than that: ſince after the power is become ſo great, as to be an overmatch for the reſiſtance ariſing from the hardneſs of the Steel, the Magnet muſt neceſſarily reduce itſelf to ſuch a power, as ſhall be juſt a balance for that reſiſtance. And if we allow this reaſoning to be juſt, the ſofter the Steel is, the leſs Magnetiſm it ought to retain, and the more eaſily it ought to be damaged. And this is actually the Caſe: for a piece of ſpring-tempered Steel will not retain near ſo much Magnetiſm, as hard Steel; ſoft Steel will retain ſtill leſs; and Iron, which is the ſofteſt of all, ſcarce retains any. And this is evidently only want of *retention:* for Iron will *receive* Magnetiſm the moſt eaſily of any; the ſoft Steel receives it much more eaſily, than the ſpring-tempered; and the ſpring-tempered much more eaſily, than the hard: for proof of this, ſee the Method of making Artificial Magnets, by means of three Iron bars, towards the End. The different ability in hard and ſpring-tempered Steel to *retain* their Magnetiſm may be ſhewn thus:

EXPERIMENT.

Take two Magnets of an equal Size, one hard, and the other only of a ſpring temper; and, placing their Poles of the ſame denomination together, rub them a little backwards and forwards for ſome time; and the ſpring-tempered Magnet will be greatly damaged, or even quite ſpoiled, when the other will be hardly the worſe.

From what has been ſaid, it appears very probable then, that the moſt likely way of improving Magnets muſt be by employing better *Materials*; which, if there are any ſuch, muſt probably be ſome kinds of Iron Ore, of thoſe ſorts that are capable of being made Magnetical: ſince different Steel, as far as has fallen under my experience, has made little or no difference; only that ſome has required greater exactneſs, or a greater or leſs degree of heat, in the hardening.

Though Artificial Magnets have not been made to ſo great perfection, as at preſent, till very lately, there have not however been wanting ſome attempts to make them, and thoſe with ſome degree of ſucceſs. Several have thought of joining a good number of bars of

Steel together, with Armour fixed to them, after having touched them on a good Loadſtone; and this has ſucceeded tolerably well, ſo as that ſome Magnets, made after this manner, were little or not at all inferior to good Natural ones. And they had been generally much better ſtill, had they been made of hard Steel, inſtead of ſoft or ſpring-tempered; which was moſt commonly uſed, from a Notion, I ſuppoſe, that ſuch bars would receive the moſt Virtue: whereas they only *receive* it with *more eaſe*, but will not *retain* it in ſo great a degree; and even what they do retain at firſt, they are much more ſubject to loſe afterwards; and particularly ſo, when ſeveral bars are laid with their Poles of the ſame denomination together, which is the caſe in theſe compound Magnets.

The beſt Artificial Magnets that ever were made, till very lately, ſeem to be thoſe of *Servington Savery*, Eſq; † which were not much inferior to ſuch, as are made by the Method here offered to the Publick, if they were ſuch as he repreſents them. And as his Method of making them ſeems to be founded on the true Principles of Magnetiſm, (for he appears to have underſtood the ſubject very well,) there can be no great reaſon to doubt the truth of what he aſſerts. But I have not thought of trying myſelf whether his method would ſucceed, becauſe it requires a good deal of time and trouble; and could be of very little uſe, when I had a much eaſier and more expeditious way of making them unqueſtionably better. It ſeems ſtrange however, that his Method has not hitherto been tried by others; and that ſuch Magnets are not before this, in common uſe, as they are greatly ſuperior to the generality of the better ſort of Natural Magnets, and perhaps to the beſt in uſe.

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† See *Philoſ. Tranſ.* N°. 414. or Vol. 6. Part 2d. Page 260. *Eames*'s Abridgment.

Though it is not altogether neceſſary to the preſent deſign, yet it may not perhaps be amiſs, juſt to mention a few properties of Magnetical Bodies; ſome of which are very neceſſary to be known by thoſe, who have a mind to try Experiments; and for want of the knowledge of which, many experiments on this ſubject have fail'd, or wrong concluſions have been drawn from them. It will however be inconſiſtent with the brevity, I here propoſe, to give the proofs of them; which therefore I muſt defer till ſome farther opportunity offers.

Firſt then, Wherever any Magnetiſm is found, whether in the Magnet itſelf, or any piece of Iron, *&c.* excited by the Magnet, there are always found two Poles, which are generally called North and South; and the North Pole of one Magnet always attracts the South Pole, and repels the North Pole of another; and *vice verſâ.*

Secondly, This Attraction and Repulſion of Magnets is not at all hindered, or increaſed by the interpoſition of any Body whatſoever; though ſometimes in *appearance* it may be either, by the interpoſition of ſuch Bodies, as become Magnetical when in contact with, or upon their approach towards the Magnets, between which they are placed.

† *Thirdly*, Each Pole attracts or repels exactly equally, at equal diſtances, in every direction.

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† This is a Property, which perhaps thoſe, who imagine Magnetiſm to depend upon a ſubtle fluid, may not be very willing to admit, as being utterly inconſiſtent with ſuch an Hypotheſis; but it is capable of being proved by a great variety of experiments.

The want of knowing this property of the Magnet has led ſeveral very accurate, and diligent enquirers into conſiderable miſtakes; amongſt whom was Dr. *Gilbert*, who wrote a very ingenious book, entitled *De Magnete*, about the end of Queen *Elizabeth*'s Reign. Not being aware of this property, he concluded from ſome experiments he had made, not very irrationally, that the Needle was not attracted by the Magnet, but turned into its poſition by, what he calls, a diſponent virtue; which he ſuppoſed to ſurround the Stone, ſomewhat in form of an Atmoſphere.

‡ *Fourthly*, The Magnetical Attraction and Repulſion are exactly equal to each other.

Fifthly, The Poles of Magnets are not at their Extremities, but at a little diſtance from thence; that is, Magnets are not ſo Magnetical at the Ends, as in the Middle; and in ſpring-tempered and ſoft Steel Magnets, the Poles are generally ſomewhat farther from the Extremities than in hard ones.

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‡ Moſt people, who have mentioned any thing relating to this property of the Magnet, have agreed, not only that the Attraction and Repulſion of Magnets are not equal to each other, but that alſo they do not obſerve the ſame rule of increaſe and decreaſe. Their miſtake in this matter aroſe from their not attending to the different degrees of Strength, that Magnets have, in different circumſtances: for two Magnets, that are placed with their attracting Poles towards each other, will have their power by that means increaſed; and on the contrary, if their repelling Poles be placed towards each other, their power will thereby be diminiſhed: and this increaſe or diminution of power will be in a greater or leſs degree, according as the Magnets are nearer to, or farther from each other; whence in all the experiments made on this ſubject, the Attraction and Repulſion come perpetually nearer to an equality, the greater the diſtance of the two Magnets is, with which the experiments are made; and *vice verſâ*. And ſo great is the effect of Magnets on each other, that, when the repellent Poles of a large Magnet and a ſmall one are brought into contact, the ſmall one ſhall ſometimes have its Repellency changed into Attraction.

* *Sixthly*, The Attraction and Repulſion of Magnets decreaſe, as the Squares of the diſtances from the reſpective Poles increaſe.

This property, from ſome experiments I have made myſelf, and from thoſe I have ſeen of others, ſeems very probable; but I do not pretend to lay it down as certain, not having made experiments enough yet, to determine it with ſufficient exactneſs.

Seventhly, Magnets lift Iron, in an increaſed *ratio* of their Strength for *touching*, *&c.* and probably very nearly in a duplicate *ratio*.

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* There have been ſome, who have imagined, that the decreaſe of the Magnetic Attraction and Repulſion is inverſely as the Cubes of the diſtances; others, as the Squares; and others, that it follows no certain *ratio* at all, but that it is much quicker at greater diſtances, than at ſmall ones, and that it is different in different Stones. Amongſt theſe laſt is Dr. *Brook Taylor*, and P. *Muſchenbroek*, who ſeem to have been pretty accurate in their experiments. [See *Philoſoph. Tranſ.* N°. 368 and 390. or Vol. VI. Part II. Page 253 and 255. *Eames*'s Abridgement.] The concluſions of theſe Gentlemen were drawn from their experiments, without their being aware of the *third* property of Magnets, juſt mentioned. If they had made proper allowances for that, together with the increaſe and diminution of power in the Magnets they tried their experiments with, all the irregularities, they complained of, (as far as appears from their relations of them) might very well be accounted for, and the whole of their experiments coincide with the Squares of the diſtances inverſely.

OF THE

METHOD

OF MAKING

Artificial Magnets.

BEFORE we come to the Method of making Magnets, it may not be amiſs to obſerve, that every Magnet has two Poles, (as they are called,) that is, two Points from which the attractive and repulſive powers ſeem to ſpread themſelves, and to which they are directed; at the neareſt parts to which, if other circumſtances be the ſame, the Magnet always acts ſtrongeſt. One of theſe is called the *North* Pole, and the other the *South*; and that is generally, and moſt properly called the † *South* Pole, which, if the Magnet was put into a little boat of Wood, or other Materials, (large enough to ſupport it,) and ſet afloat in water, would turn itſelf towards the *North*: and that is moſt properly called the *North* Pole, which would turn towards the *South*. This is the Senſe, in which I would always be underſtood when I ſpeak of them.

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† This is the Senſe in which they are always underſtood by the beſt Authors. [See *Gilbertus de Magnete.* Mr. *Savery* in the *Philoſ. Tranſ.* and ſeveral others, that have written upon this Subject.] The Reaſon of calling them thus, is, that the Pole of the Magnet, which turns towards the *South*, is of the ſame kind with the *Northern* Magnetic Pole or Poles of the Earth; and contrariwiſe.

A *South* Pole of one Magnet always attracts the *North* Pole of another, and repels the *South* Pole; and on the contrary, a *North* Pole attracts the *South* Pole, and repels the *North* Pole of another. If any one therefore has a mind to touch a Needle, whoſe Point he would have turn towards the *North*, he begins by placing the other end of the Needle on the *North* Pole of the Magnet; and drawing it gradually along, he finiſhes with the Point: for the Point being laſt attracted, will continue to be attracted by the *North* Pole of the Magnet, and the other end will be repelled by it. And becauſe the Point is attracted by a *North* Pole, it follows from what was ſaid above, that it muſt be itſelf a *South* Pole, and conſequently will turn towards the *North*, which is what was required.—— Thus much to have premiſed may be ſufficient.——Let us now proceed to the Method propoſed for making Magnets.

Prepare a dozen bars of Steel, of about an ounce and three quarters weight each, ſix inches long, and half an inch broad; let theſe be hardened with a *full* heat, but not with *too* *great* an one, for that is as bad as the other extreme. Theſe bars ſhould all be marked at one end, in order to diſtinguiſh one end from the other; and this may be done conveniently enough by nicking them all round near the end with a Chizel. The *ends* of the bars ſhould be cleaned up after hardening, either upon a ſmooth Stone, or Razor-grinder's Wheel, in order to make them ſhew to advantage in lifting of weights, and perhaps to make them a little better for touching Needles, *&c.* It may not be amiſs too, for thoſe who require beauty, to have the whole bar cleaned up after the ſame manner; but it is by no means neceſſary: for the bars that are hardened, as they come from the Forge, without any labour beſtowed upon them, are to the full as ſtrong as the others, and generally rather ſtronger.

The foregoing is propoſed as a convenient Size and Shape. But if any other is liked better, either may be varied at pleaſure, provided there be always obſerved a proper Length in the bars in proportion to their Thickneſs; an account of which may be ſeen in the Table hereafter inſerted.

As the bars here propoſed are deſigned to be employed in making of Magnets of all Sizes, if any Perſon deſigns to make very large ones, he muſt have a great many more than a dozen. And it will likewiſe be very proper to have a good many of about half an inch longer, or half an Inch ſhorter than the reſt; the reaſons of which will be ſeen hereafter.

The beſt ſort of Steel, to make theſe bars of, is ſuch as has no Veins of Iron in it; and probably in general, that which will receive the greateſt degree of hardneſs, and with leaſt heat. I have ſometimes given the preference to double-refined Steel; ſometimes to *German*; and as often to the common bliſtered Steel; which I may venture to recommend as equal to any that I have tried; for the difference in Magnets made of any Steel whatſoever, ſeems to ariſe chiefly from the different degrees of heat given them, in order to harden them; which will make a very great difference in the ſame Steel: but the bliſtered Steel ſeems both as certain, and as little liable to any difference from little variations in the degree of heat given it, as any.

It will be proper, when any Magnet does not prove ſo good as expected, to harden it over again with a greater or leſs degree of heat, till it proves better. One of the beſt ſix-inch bars, I ever made, was one of the worſt, till it had been hardened ſix or ſeven different times. As the common bliſtered Steel is as good for our purpoſe as any, a dozen ſuch bars, as thoſe deſcribed above, together with a proper box to put them in, may be afforded for a very ſmall ſum; and ſuch a Set is capable of touching a much larger Needle, than the beſt *Natural* Magnet yet diſcovered. In order to preſerve theſe bars, it will be proper to have a box contrived, that ſhall have two pieces of Iron, of about an inch long each, (which will be about equal to the thickneſs of half a dozen of the Magnetical bars,) fixed upright, in the middle of each end, over againſt each other, at the diſtance of ſix inches from outſide to outſide. Theſe pieces of Iron may be about a quarter of an inch ſquare, or ſomewhat more, and ſhould be filed pretty ſmooth on the ſides. Againſt theſe are to be placed, with their Edges towards them, the dozen Magnetical bars, ſix on one ſide of them, and ſix on the other; the ſix on one ſide with their South, (or North) Poles *one* way, and thoſe on the other ſide with the ſame Poles the *contrary* way.—And here it is to be obſerved, that they muſt neither be taken out, nor put in all, or too many on a ſide at once; for if two only be left, with their Poles of the ſame denomination the ſame way, without one or more on the other ſide to counterbalance their effects, they will damage each other: and if two of the ſame ſide be taken out together, or laid with their Poles of the ſame denomination together after they are taken out, they will alſo damage one another; and this ought always carefully to be attended to. But, if at any time they are damaged, either for want of taking this precaution, or by any other Means, it will be proper to reſtore them, before they are uſed, after the manner preſcribed for making of Magnets.

The bars being prepared as above, let it be propoſed to make the marked ends of them South Poles, and the unmarked ends North Poles. To do this, place half a dozen of them in a line North and South, bringing the unmarked end of one to touch the marked end of the next throughout; the marked ends lying towards the North, which will be ſome advantage to them. This done, take an *armed* Magnet, and placing it with both Poles upon one of the bars, the North Pole towards the marked end, (which is to be a South Pole,) and the South Pole towards the unmarked end, (which is to be a North Pole;) ſlide it backwards and forwards, from end to end of the whole line of bars, three or four times, taking care that they all touch. Then taking it off, remove the two endmoſt bars into the middle, and paſs over them again three or four times: this is directed, becauſe the two endmoſt bars of the line will not receive ſo much virtue as the reſt; and thoſe, that have been touched whilſt in the middle, ought never to be paſſed over again, when placed at the ends; becauſe they would be ſo far from acquiring any new virtue by it, that they would loſe part of what they had got already. Having touched the bars in the foregoing manner, it will not be improper to turn them the other ſide uppermoſt, and touch them over again on that ſide, in the ſame manner, excepting the endmoſt bars, (for the reaſon juſt mentioned;) which, when the reſt are touched, muſt be removed into the middle, and be touched in their turn.

If an *armed* Magnet is not to be had, take an *unarmed* one, either Natural or Artificial: and, laying the bars in a line as before, place the South Pole of the Magnet upon the marked end of the endmoſt bar, and ſlide it over the whole line to the end; then taking that Pole off, place the North Pole upon the ſame bar in its room; not at the extremity of the bar, but towards the middle, and ſlide it back again: then, change the Poles again, (taking care to ſet the Magnet on at the middle of the bar,) and ſlide it to the other end, as at firſt. Having done this four or five times, remove the two endmoſt bars into the middle, and placing the South Pole of the Magnet upon the marked end of them, ſlide it to the unmarked end; and then, placing the North Pole upon the unmarked end, ſlide it to the marked end. Let this be repeated three or four times; and turning the bars the other ſide upwards, repeat the ſame proceſs again.

If the Magnets made uſe of in either of theſe Methods, ſhould be too weak to communicate to the bars a ſufficient degree of virtue to proceed with, (which may poſſibly be the caſe, eſpecially in the laſt, and perhaps ſometimes in the former, when the Poles are at a great diſtance;) it may not be amiſs to touch the bars according to the foregoing directions, before they are hardened, when they will receive the Magnetic Virtue with much more eaſe: then, making the whole dozen Magnetical, according to the method hereafter given, till they are as ſtrongly ſo, as they will be in their ſoft ſtate, harden one half; and having made theſe again Magnetical with the remaining half that are ſoft, harden thoſe alſo, and proceed.

But if the Magnets be ſo very weak, as not to perform ſufficiently even in this caſe; recourſe muſt be had to ſmaller bars of Steel, than thoſe of ſix inches, and theſe ſoft too. And if after all, this will not do, bars of Iron muſt be uſed, inſtead of the Magnets, after the manner deſcribed towards the end.

Having communicated a ſmall degree of

Magnetiſm to half a dozen of the bars; let the other half dozen, that remain yet unmagnetical, be laid in a line, in the ſame manner as the former; and let A B in fig. 1ſt repreſent this line, conſiſting, according to the preſent ſuppoſition, of ſix bars, though in the figure only three are delineated, for want of room. The line drawn croſs at the end of each bar towards the right hand, repreſents the mark to diſtinguiſh that end from the other, and which in the preſent caſe we propoſe to make a South Pole. Let C D, E F, repreſent the half dozen bars, already made Magnetical; of which C D contains three, and E F three: theſe are made to lean againſt each other at the top, but are ſeparated to a ſmall diſtance at bottom, perhaps a tenth of an inch, or a little more; though at firſt, while they are weak, they can hardly be brought too near, provided they do not touch, which they muſt by no means do. It will be convenient to place between them a little bit of Wood, or any other Material, except Iron, to keep them at their diſtance. The three Magnets in C D, (for ſo we may properly enough call them, though their power as yet may be very ſmall,) have all their South Poles downward, and placed towards the unmarked ends of the bars in the line, which are to be North Poles; and the three Magnets in E F, have all their North Poles downward, and theſe are placed towards the marked ends of the bars, which are to be South Poles. [As in CD, EF, the marks upon the flat ſide of the Magnets are hid in ſeveral of them, there are little dots made on the edges, to diſtinguiſh the South Poles by, in the figure.] Theſe ſix Magnetical bars being thus placed, ſlide them backward and forward three or four times, the whole length of the line. Then taking them off, having firſt brought them to touch at the bottom, remove the two endmoſt bars of the line into the middle; and replacing the Magnetical bars, ſeparated at the bottom as before, upon them, paſs over thoſe again. Then take off the Magnetical bars again, and, turning the bars in the line, the other ſide upward, go over them again, in the ſame manner, excepting the endmoſt bars; which, when thoſe in the middle are touched, are to be removed thither, to be touched in their turn. If the bars that were firſt made Magnetical had acquired a ſufficient degree of virtue from the Magnet made uſe of to begin with, this ſecond half dozen will, by the means here recommended, have acquired a ſtronger power than the former, which they were touched by; and therefore we may now lay down the firſt half dozen, in a line as before, and retouch them, after the ſame manner, with the latter, which have juſt received their Magnetiſm from them: this done, lay thoſe down alſo again, and retouch them with the others: Repeat this a few times, firſt touching one Set, and then the other, till they have acquired as much Magnetiſm, as they will retain; or till they will receive no additional force, by any farther repetitions.

The ſix-inch bars made Magnetical after this manner, when properly hardened, will ſingly lift by one Pole a piece of Iron, weighing a pound or better, if it is of a proper form: and ſix ſuch bars, uſed according to the foregoing directions, will touch a line of freſh bars, of the ſame ſize, to their full perfection, in three or four times ſliding over them; except the endmoſt, which muſt be always removed to the middle.

In the Method here given, three of the Magnetical bars (which are made uſe of to touch the others,) on one ſide, are ſet with their North Poles downward; and the other three on the other ſide, with their South Poles downward. Now as ſeveral Magnets laid together, with their Poles of the ſame denomination the ſame way, will greatly injure one another, unleſs they have ſomething to counteract them; it is abſolutely neceſſary, (and it ought always carefully to be obſerved,) not to place two of them, of a ſide, on together; but ſingly, one on one ſide, and one on the other, leaning them together, that they may reſt againſt one another at the top: at the bottom they are preſerved from injuring one another, by being placed upon the bar which is to be made Magnetical. In like manner they muſt not be taken off two of a ſide together; but ſingly, firſt on one ſide, and then on the other. But the readieſt way of taking them off, is firſt to bring them to touch one another at the bottom, in the ſame manner as they do at the top, and then they may be removed at once, and upon occaſion ſet on again; only obſerving not to ſeparate them again, at the bottom, till they are placed upon the bar, they are to touch.

The two bars, at the ends of the line, are directed to be removed from thence in their turn; becauſe they will not receive ſo much virtue there, as when placed in the middle. The reaſon of this ſeems to be, that the ſix Magnets, employed in touching, are endeavouring to make that Part of the bar which is *not* included between them, Magnetical in a *contrary* direction from that, which *is* included between them. Now this laſt is the direction of Magnetiſm deſigned; and conſequently that former Endeavour is againſt us, and would do miſchief, were it not by ſome means prevented; and to prevent it, there are two cauſes that concur; one, the power, by which the Steel reſiſts in a certain degree all Endeavour, either to make it Magnetical, or to deſtroy its Magnetiſm; the other, the power of the bars already in ſome meaſure Magnetical, which lye at both ends of the bar that is touched. Now this laſt power is wanting at one extremity of thoſe bars, that are placed at the ends; and conſequently not having a ſufficient force fully to reſiſt the *contrary* Endeavour of the Magnets employed in touching them, they become leſs Magnetical than the others, which have a ſufficient force. Though in the line of bars, when making Magnetical, each bar has only one at each end to † ſupport it againſt the *contrary* Endeavour of the ſix, made uſe of to touch it; and this does very well: yet ſome will receive ſome additional force by being ſupported with larger Magnets; or inſtead of that, two or three of their own ſize, at each end; thoſe at the marked end all with their North Poles touching it, and thoſe at the unmarked end all with their South Poles touching it. And becauſe there will be two or three North Poles, and as many South Poles, together amongſt the Supporters, at the other end from the bar to be touched, that have nothing to counteract them, it will be proper to place the South Pole of another Magnet amongſt the North Poles, and the North Pole of another amongſt the South Poles, that they may not hurt one another, which they otherwiſe will do.

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† Thoſe Magnets, that are placed at the ends of the others, to preſerve them, I call *Supporters.*

If more Magnets, than ſix, are uſed to touch bars of their own ſize, the *contrary* Endeavour will be greater; and conſequently they ought not to touch ſo well as fewer, unleſs the bars to be touched, are more ſtrongly ſupported. Hence eight Magnets will not touch a line of bars ſo well, as ſix; for one ſupporter at each end, is not ſufficient againſt the *contrary* Endeavour of ſo many.

As eight Magnets have a greater power than ſix, and therefore muſt certainly communicate a greater power to a bar, if it is ſufficiently ſupported; it may be aſked, why ſhould we not contrive to ſupport it ſufficiently, and make uſe of eight? To this I anſwer, that ſix are abundantly ſufficient, to communicate as much power to a bar of their own ſize, as it will retain; and indeed, a good deal more: Four only are not much inferior to ſix; and two will give a power not a great deal leſs than either of thoſe numbers. But if any one chuſes to try eight, or a much greater number, (though it is not an eaſy matter to *ſupport* againſt the *contrary* Endeavour of a great many,) he may, by the following means, touch a very ſmall bar with almoſt any number he pleaſes. Place upon the bar to be touched any number, in the ſame manner as the ſix are ordered to be placed, *viz.* half with the South Poles downward, towards one end; and the other half with the North Poles downward, towards the other end: And in caſe there be not otherwiſe convenient room to place ſo many as deſired, they may be placed in double order upon the bar, only one half of each ſtanding upon the bar, and the reſt hanging over. Theſe, inſtead of being made to lean at the top againſt each other to preſerve them, may be made to lean with their edges againſt a piece of Iron, the length of the bar to be touched; or (if they are placed in double order,) againſt two ſuch pieces of Iron: then the two Sets, *viz.* thoſe with their North Poles downward, and thoſe with their South Poles downward, being placed ſo near each other as almoſt to touch in the middle, they may be gradually drawn from each other to the ends.

After this manner it may not be amiſs to touch very ſmall Needles, that are ſo ſlender as not to be able to ſupport themſelves againſt the *contrary* Endeavour, though they be touched with only two of the ſix-inch Magnets: but in this caſe, there will be no occaſion for the pieces of Iron mentioned above; as it will not be at all neceſſary to uſe more than two Magnets to touch them with, which will want no connection to preſerve them.

The manner of making Artificial Magnets, ſhewn in the foregoing Pages, may not improperly be called the *double Touch.* The reaſon why the Magnets uſed in it are to be placed in the manner directed, and why they give that direction of Magnetiſm which they do, cannot but be obvious enough to thoſe, who have at all thought upon this ſubject: And many of the advantages the *double Touch* has over the *ſingle*, or common way of touching, are alſo very plain. In the common way, the ſtrength of only a Pole of one denomination, and of one Magnet can be applied; and if this ſhould not be ſtrong enough, to give as great a degree of Magnetiſm to a bar of Steel, as it will retain, we cannot add to it, by applying ſeveral Magnets, with their Poles of the ſame denomination together, and touching upon them as if they were one; ſince Magnets, placed with their Poles of the ſame denomination together, will greatly damage each other; and if there be many of them, they will utterly ſpoil *ſeveral*, and greatly damage the *reſt.* If therefore we wanted to touch a bar, that would require the ſtrength of thirty of the ſix-inch bars, or more, after the manner of the *ſingle Touch*, it would be utterly impoſſible; ſince we could by no means collect force enough together, on account of their ſpoiling each other: but if we take one half of the number of bars, and ſet them the other ends upward, over againſt the reſt, after the manner in the *double Touch*; they will then not only *preſerve* each other almoſt intirely; but it ſhould ſeem, that they will alſo in ſome meaſure *increaſe* the ſtrength of the *ends*, which principally are concerned in touching.

There is a ſmall advantage in the *double Touch*, ariſing from the two Sets of Poles being near each other; ſo that they counteract, in ſome meaſure, the *contrary* Endeavour of one another.

Two Magnets will give more ſtrength to a bar of their own ſize, when uſed after the manner of the *double Touch*, than a ſingle Magnet equal to five of the former in ſtrength, when applied after the manner of the *ſingle Touch*. To ſet them however in a fair light, we ought to reckon the two as nearly equal to four; becauſe they have the double aſſiſtance of what they touch, after it is once become at all Magnetical; and (becauſe all Magnets are much ſtronger in the middle, than they are at the ends,) this aſſiſtance may perhaps be nearly equal to the ſtrength of the two Magnets, that are employed: whence we ought to reckon a force nearly equal to four of the ſingle bars, in this manner of touching, againſt a little more than the five in the ſingle touch, where the Magnetiſm of the bar touched is of very little aſſiſtance, the part lying behind the Magnet employed in touching, being generally Magnetical by the force of it in a *contrary* direction, from that which lies before the Magnet, and conſequently nearly counteracting it.

When I firſt thought of trying the *double Touch*, I promiſed myſelf great advantages from it; ſeeing from other experiments a great probability, that the only thing wanting to make Steel very Magnetical, was to apply a ſufficient force; and by the means of the *double Touch*, I did not doubt of being able to apply almoſt any force, I would: But I did not expect that there would be ſo great a diſproportion between it and the *ſingle Touch*, as I have ſince found: neither am I thoroughly ſatisfied, that there is not yet ſome other reaſon wanting to account for it, beſides thoſe already given; which ſeem hardly ſufficient to account for the whole of it.

All Needles ſhould be touched *double*, and well ſupported, in order to be ſure of giving them their full force: And it is well worth obſerving, that (for the reaſons already aſſigned) care ſhould be taken to make them of hardened Steel, and by no means of ſoft, or even ſpring-tempered. And there is another advantage in making Needles hard, beſides their retaining more power, and loſing their power with more difficulty, *viz.* that the Poles of ſuch, according to the *fifth* property of Magnets, mentioned Page 18, are nearer the extremities, and conſequently act with more force to turn the Needle about.

For Mariner's † Needles to carry a Card, it will be very proper, to uſe ſuch bars as thoſe propoſed for Magnets, (or however but little ſmaller in proportion to their Length,) with a hole in the middle, to let the pin, they are to reſt on, paſs through, and to faſten a cap in. The reaſon why I would recommend ſuch large bars, is becauſe the larger quantity of Steel we uſe, the more ſteadily and certainly the Compaſs will traverſe, (provided the Needle be as Magnetical in proportion to its bulk, as a more ſlender one; and this, ſuch as are here propoſed may be;) but they ſhould not be much larger, for then that will not be the caſe.

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† Perhaps it may not be amiſs to cover the Needles, made uſe of in the Sea Service, with a very thin coat of Linſeed Oil, or ſome kind of Varniſh, that may keep them from ruſting, which is generally reckoned to injure all Magnetical bodies that are liable to it. Needles may be touched through ſuch a coat, as well as when naked, if *not* according to the method for making of Magnets, at *leaſt* by a great number of bars applied after the method recommended for making ſmall bars Magnetical. [See p. 33 and 34.] But probably the former Manner will be effectual; for I have given a very conſiderable ſtrength to bars, though a card (which is many times thicker than ſuch a coat,) was placed between them and the half dozen bars made uſe of to touch them. And *poſſibly* ſuch a coat (eſpecially of Linſeed oil,) may make the Needles in time able to retain a greater degree of Magnetiſm, than they otherwiſe would do; for I have obſerved that *painted* Iron Caſements are very often remarkably Magnetical; and it is generally ſaid too, that they become much harder, and more brittle, for being painted; which perhaps may be the reaſon of their being ſo remarkably ſuſceptible of Magnetiſm.

There is one objection however to the making uſe of ſuch large bars for Needles, eſpecially if they are broad at the ends, which is this; that we cannot in ſuch be always ſure of having the * Axis exactly in the middle of them: This however may in ſome meaſure be ſecured, by uſing bars pointed at the ends, ſuch as fig. 2d. But as in ſuch bars the Poles will be removed ſomewhat farther from the ends, and conſequently the Needle will thereby be made *ſhorter*, if not leſs *Magnetical* too, in proportion to its ſize; it ſeems rather adviſeable to adjuſt this inaccuracy, by comparing it with a long and ſlender Needle, without a Card; which may be done very conveniently, eſpecially on Shipboard, by ſtretching a line, and placing both Needles under it, at a good diſtance from each other, that they may not affect one another; and then adjuſting the Card, upon that which is to carry it, by the line.

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* The Axis of a Needle, or Magnet, is a line paſſing through the two Poles; which is its line of direction, from which we muſt reckon its variation, *&c.*

There is an inconvenience will ariſe from increaſing the Weight of Mariners Needles; *viz.* that the friction will be increaſed with it, and that in a greater proportion than the power of the Needles to turn themſelves about, if they are made with metal caps, to turn upon metal points; eſpecially if Steel points are not uſed, which are ſomewhat inconvenient at Sea, where every thing of Iron or Steel is ſo extremely ſubject to ruſt. To remedy the friction in this caſe, it will be very proper to make uſe of caps, that have a little bit of Glaſs or Agate ſet in the top: This bit of Glaſs or Agate ſhould have a hollow to receive the Point, ground on the underſide, which ſhould be very accurately poliſhed. It may not be amiſs, perhaps, to make the Point, that this is to turn upon, of Silver, or (which will be better) of Gold, made very hard by a good deal of allay; theſe are not either of them ſubject to ruſt, eſpecially not the Gold. Such caps and points as theſe, need be very little additional expence to any compaſſes; and compaſſes, furniſhed with ſuch, may be depended upon to a much greater degree of exactneſs, than is neceſſary, or than it is poſſible to ſteer to, when there is not the leaſt breath of air to ruffle the Water, or the leaſt ſwell to cauſe any Motion in the Ship; and this without the attendance of a perſon to tap the box, in order to take off the friction; which in the common compaſſes is often neceſſary, if it be required that they ſhould traverſe with any degree of accuracy.

I faſtened ſuch a cap as that deſcribed above, with a Glaſs top, to a Needle that weighed ſomewhat more than eight Ounces, and which was 32 inches long: This Needle was ſet a going at the rate of about twenty five times round in a minute; and with this force, it made complete revolutions for the ſpace of ſeventeen or eighteen minutes; after which it continued to vibrate about fifteen minutes longer, before it came to be quite at reſt; and this it did upon a very irregular and blunt Braſs point, which it had made ſo by its weight. The ſame Needle reſting upon a ſharp and well poliſhed Steel point in Braſs, would hardly vibrate at all. This Needle, with the glaſs cap, performed its ſmaller vibrations, which were nearly of equal time, in about thirteen ſeconds; and though large Needles do not vibrate very faſt, in proportion to the ſmall ones, yet this would probably have vibrated conſiderably faſter, had it been properly hardened; for it was ſo long, that it was with ſome difficulty hardened at all by ſuch Workmen, as I was able to procure; and therefore being at laſt too ſoft, it would not become near ſo magnetical, as otherwiſe it might have been.

There are many Occaſions, where theſe long Needles may be very uſeful; and particularly on account of their traverſing to a much greater degree of exactneſs than the ſhort ones, if they be well hung, as upon Glaſs, *&c.* which is almoſt abſolutely neceſſary. There is one caſe where they may be of conſiderable ſervice; which therefore it may not be improper to mention.

It is ſaid, that it is common to make uſe of Needles in Mines, (particularly of Coal,) in order to know the bearing of one place from another, that they may be able to ſink a Shaft from above, over any place they will: But as in many ſorts of Mines, and particularly thoſe of Coal, there are often ſmall quantities of Magnetical Iron Ore, they are very often thereby deceived, the Magnetical Iron Ore drawing the Needle out of its proper direction: Now the long Needles, beſide their traverſing to a greater degree of exactneſs, are leſs liable to be diſturbed by any ſmall things, already † Magnetical, than the ſhorter ones. However, as, after all, the long Needles will be liable to be ſomewhat diſturbed by parcels of Magnetical Iron Ore, that may chance to lye near; the following method may be uſed, which will hardly ever fail of diſcovering ſuch, if there be any; and will point out a way to rectify very nearly any error, that may be occaſioned thereby. Stretch a Line, as long as conveniently may be, in the Mine; and placing the Needle under it at one end, obſerve whether the Needle coincides with it, or at what angle it interſects it; then removing the Needle from place to place under the line, obſerve whether it always retains the ſame direction with reſpect to it; and if it does, its direction may be looked on as true, with hardly a poſſibility of being deceived: But if it varies in its direction in different places, then the place or places, where it deviates moſt from its general direction in other places, or where it varies quickeſt in moving the ſame diſtance along the line, muſt be neareſt the occaſion of its varying; and then the farther one can remove from ſuch place or places, the better. And after all, a little may be allowed for the varying of the Needle towards, or from ſuch place or places, according as it ſhall appear, that its North or South Pole, which was there attracted, is neareſt to, or fartheſt from any ſuch. And in order to find which was attracted, remove the Needle to a little diſtance, in a direction at right angles to the line, firſt on one ſide, and then on the other; and obſerve on which ſide it deviates moſt from its general direction in other places: And then that end of the Needle which deviates there towards that *ſide*, or from the *line*, is the end attracted. But if, on either ſide of the line, the Needle ſhould chance, when removed a little way, to deviate a good deal; and when removed a little farther, to deviate not at all; and when removed a little farther ſtill, to deviate the other way; then the ſubſtance attracting the Needle is nearly over or under it, at the point where it does not deviate at all: This therefore ſhould be carefully obſerved, leſt the Needle happening to be placed in this ſituation, where it does not deviate at all, the other ſhould be taken for the ſide, where the attracting ſubſtance lyes, which may occaſion a conſiderable error.

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† Theſe large Needles indeed are rather more ſubject, than ſmaller ones, to be diſturbed by any thing capable of being made Magnetical by *themſelves*, as their power is ſtronger at a diſtance; for this reaſon all Iron, as Picks, &c. ſhould be the more carefully kept at a good diſtance from them; and this indeed ſhould be obſerved, when *any* Needles are uſed.

The ſix-inch bars are very ſufficient for any purpoſes of touching, and they are ſuch as are moſt likely to be generally uſeful; and as it is probable that Needles of a greater thickneſs than they are, will hardly ever be uſed, the foregoing directions might perhaps be ſufficient. But becauſe ſome may chuſe to make larger Magnets than thoſe of ſix Inches, as alſo of different Shapes, for the ſake of variety and curioſity; and it will require ſome experience to be able to manage them conveniently, and to know how many of the ſix-inch bars are proper to be uſed in touching them, *&c.* the following directions are inſerted.

All bars made uſe of for Magnets muſt be made of Steel, and hardened according to the directions given for the ſix-inch bars: And in order to hold ſo great a number of ſix-inch bars, as muſt be employed in touching the large bars, it is neceſſary to make uſe of ſome kind of Frame; it being impoſſible to hold them in the hand, as one may the ſix for touching the ſmall bars. The following is a deſcription of a Frame for this purpoſe.

Let fig. 3d repreſent a Frame for holding ſeveral of the ſix-inch bars, in order to touch large bars; at the bottom of the Frame are placed two pieces of Wood, the ends of which are ſeen at A and B; the diſtance of theſe pieces from each other muſt be a little more than the breadth of the bar to be touched, which is to ſlide eaſily between them: The deſign of theſe two pieces is to keep the Frame ſteady upon the bar, that it may not ſlide off ſideways, when it ſhould not; but as it will be ſometimes required to ſlide it off ſideways, theſe muſt be either made ſo as to be taken off occaſionally, or, they muſt be entirely omitted. The height of the Frame, without theſe two pieces, is ſix inches, being the length of the bars employed in touching; it conſiſts of four upright pieces framed together at the top and bottom by two open Frames, each of which is divided into two partitions by a croſs bar in the middle, of about half an inch wide. Theſe partitions are to hold, one of them a Set of bars with their South Poles downward, and the other a Set of a like number with their North Poles downward; and they are ſuppoſed wide enough to hold two breadths of the ſix-inch bars, which will be almoſt an inch and quarter; and, becauſe this may be more than the breadth of the bar to be touched, the two pieces A and B in that caſe will be nearer together than the two ſide pieces of the Frame; and the ſix-inch bars, when placed in double order, will hang over the pieces A and B; and therefore, that they may not reſt upon them, and be thereby born off from the bar they are to touch, the three tranſverſe pieces of the Frame at bottom are all ſuppoſed to be notched in a little way, to allow a little liberty. In the frame-work at the top are two hollows, one on each ſide, (that on the farther ſide only is viſible in the figure;) theſe hollows are to be large enough to receive, each a piece of ſoft Iron, of about half an inch broad, and a quarter thick, or ſomewhat larger; and yet leave as great a diſtance between them, as to contain two breadths of the ſix-inch bars; that is, almoſt an inch and quarter, which is the breadth of the open partitions.

Theſe two pieces of Iron are to be filed pretty ſmooth on that ſide, which is placed inwards; they are deſigned to connect the bars in one partition of the Frame, with thoſe in the other; one half of the bars in each being to lean againſt each of them. And, as leaning the bars againſt one another, (as was done, when ſix only were employed,) cannot be conveniently applied, when many are made uſe of; ſome ſuch contrivance as this is abſolutely neceſſary, to preſerve the bars in each partition from ſpoiling one another; which, becauſe they all lye with their Poles of the ſame denomination the ſame way, they would certainly do, if thoſe in one partition were not connected with thoſe in the other. But this will preſerve them; becauſe the Poles of one Set lye in the contrary direction from thoſe of the other.

The Frame being made as above, and the two pieces of Iron put into the hollows at the top, place it upon one bar of a line of large ones to be made Magnetical; and ſet a * proper number of the ſix-inch bars in each partition; not all at once in either, but ſingly, one in one, and one in the other; thoſe in one, with their South Poles reſting upon the bar, and their North Poles leaning againſt the pieces of Iron above; and thoſe in the other, with their North Poles reſting upon the bar, and their South Poles leaning againſt the pieces of Iron above: the North Poles reſting upon the bar being towards the marked end of it, (which is to be a South Pole,) and the South Poles towards the unmarked end of it, (which is to be a North Pole.) This being done, ſlide the Frame backwards and forwards upon the line of bars, three or four times; and, turning them, touch them on every ſide, if ſquare; or on the two flat ſides, if flat; and remove the endmoſt into the middle, and paſs over them again.

As the ſix-inch Magnets, ſo probably thoſe of a larger ſize alſo, will often receive ſome additional

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* For the number of ſix-inch bars neceſſary to touch bars of different ſizes, ſee the Table hereafter inſerted.

ditional ſtrength, by being ſupported by more than one of their own ſize at each end: if therefore it be required to give one of them the utmoſt power it will receive, it may not be amiſs to ſupport the ends of it by two or three of its own ſize; or inſtead of that, by as many of the ſix-inch bars, as may be equivalent to them. But becauſe ſo many cannot perhaps be always placed at the end of a bar, as may be required, it will do as well to place ſome of them at the ſides, as near the end as conveniently may be. The ends of the Supporters, which do not touch the large bar, being, at either end of it, all Poles of the ſame denomination, muſt be again ſupported by a few others, that they may not damage one another; theſe muſt be ſupported by others; and thoſe again perhaps by others, and ſo on: and this muſt always be obſerved, whenever a great number of Supporters are uſed, unleſs the Supporters at one end can be connected with thoſe at the other, by means of a bar of Iron as large, or ſomewhat larger than the bar of Steel to be made Magnetical. And becauſe the ſupporters may damage one another at the ends that lye next the bar ſupported, for want of ſufficient force to counterbalance their effects, before the bar is become Magnetical; it will be convenient perhaps, after having touched it, to place a freſh Set of ſupporters at the ends of it, and touch it over again. In making a bar, thus ſupported, Magnetical, becauſe the Frame cannot be ſlid off at the ends of the bar, it will be neceſſary to leave out the two pieces of Wood A and B; and then it may be ſlid off ſideways upon a bar of Iron, and on again from the bar of Iron, (as it ſhall be required,) in order to turn the Steel bar, that it may be touched on every ſide, *&c.* The bar of Iron is deſigned to connect the Poles of the two Sets in the Frame, which were before connected by the Steel bar; and they muſt not be taken off from one, and placed upon the other, but by ſliding; becauſe they muſt touch one, before they leave the other, that they may always continue connected.

The Frame above deſcribed is deſigned for touching ſuch bars only, as require no more than two breadths of the ſix-inch bars; but if it be required to touch larger bars, that will take three, four, or more breadths of them; another ſort of Frame, and the ſix-inch bars, with others of different lengths (ſuch as were directed to be made at the beginning for this purpoſe) muſt be uſed; the higher bars being to be placed in the middle, where they may be connected, by leaning againſt pieces of Iron, that paſs over the tops of the ſhorter ones.

If the bars, to be made Magnetical, are ſo large as to require ſeveral breadths of the ſix-inch bars, it will perhaps be convenient to have the Frame, for holding them, ſo contrived, that they may be applied to all ſides at once; for otherwiſe, upon account of the great number of them that will be neceſſary, it is likely the outſides of the Sets will be driven to too great a diſtance from each other, to be able to do much ſervice.

The foregoing manner, of applying the ſix-inch bars, will probably ſerve for touching bars of three inches ſquare: but if larger than theſe were to be made, perhaps it might be neceſſary, beſides applying them to all the ſides at once, to divide the two Sets, aud uſe them after the † manner recommended for making ſmall bars very Magnetical; and in that caſe, it would be impoſſible to uſe too many to touch with, and there would be no occaſion for ſupporters.

The particular *Form* of Magnets is of very little conſequence, with regard to their receiving the Magnetic Virtue, provided they have a ſufficient length in proportion to their bulk; the Form therefore may be varied at pleaſure.

The ſtrait bars may be made either ſquare, round, or flat; the flat ones however are moſt convenient for touching with, and perhaps too a little the ſtrongeſt.

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† See Pages 33 and 34.

The ſtrait bars may be pointed at the ends, in the manner of Fig. 2d in the Plate. This, in lifting, will make them ſhew to advantage upon a double account, *viz.* that they are thereby ſomewhat lighter, and that they will lift ſomething more. Theſe bars however I would not recommend for touching with; becauſe, though they may be more Magnetical at their ends, than thoſe that are not pointed, in proportion to the *ſize* of the ends; and therefore, coming to bear perhaps in as many points as the others, they may lift more; yet, the power in touching, not being only in the proportion of the points that bear upon the bar to be touched, but in a great meaſure alſo in the proportion of the Magnetiſm of the whole that is near bearing, they may not touch ſo well as thoſe with the larger ends; which have more Magnetiſm at their ends in the whole, though not ſo much in the ſame ſpace.

Beſides the ſtrait bars, the following ſeem moſt likely to be ſuch as will be more generally uſeful.

The *Horſe-ſhoe* Magnet: This may be made either exactly in the Form of an Horſe-ſhoe, or ſuch as is delineated in Fig. 4th, where a wedge of Iron is ſuppoſed to be applied to the

Poles of it. The principal advantages of a Magnet of this Shape, are; That it will lye in a narrower compaſs: A wedge of Iron may be applied to the two Poles of it; by which means, being connected, the Magnet will be leſs likely to receive any Injury by time, *&c*: It will lift by both Poles at once, and conſequently lift at leaſt double of what it would do, if it lifted only by one: It will ſerve inſtead of ſeveral ſmall bars, for touching others, if it be made of a proper ſize, and its two Poles brought near enough to each other; and it will be very convenient and expeditious for that purpoſe.

The *Annular* Magnet is a plain flat bar, bent flatways, inſtead of edgeways as the foregoing. This may be uſeful for ſeveral Experiments, and is of a very convenient ſhape to be armed.

The *Semicircular* Magnet may be bent either flatways as the *Annular*, or edgeways as the *Horſe-ſhoe* Magnet. A Magnet of this ſort is delineated in Fig. 5th. Two ſuch as this may be conveniently placed together, in order to preſerve each other: They are uſeful for touching ſmall things *double*; and for ſeveral Experiments.

The *armed* Magnets, of all kinds, being things of Curioſity rather than Uſe, and vaſtly inferior to the *unarmed* ones, ſhall be mentioned bye and bye in the Method of improving *Natural* Magnets, &c.

The method of making the abovementioned crooked Magnets is the ſame, as for the ſtrait ones. The ends are to be * ſupported in the ſame manner: The ſix-inch bars for touching muſt be placed in the ſame manner, and moved round, according to the bend of the bar, from end to end, and back again four or five times.

And now having ſaid thus much, and given ſo full a deſcription before of the method of making the ſtrait bars Magnetical, I apprehend more will be needleſs.

After the like manner that a bar is made Magnetical, its Poles may be converted; by placing the bars which are to retouch it, with their North Poles towards the North Pole of it, and the South Poles towards the South Pole of it. In doing this, they ſhould be placed on at the middle, (for otherwiſe they will perhaps be a little damaged by the Magnetiſm of it,) and ſhould be ſlid once or twice backwards and forwards, before it is ſupported; and then that, which was the North Pole, muſt be ſupported as a South Pole, by North Poles; and that, which was the South Pole, as a North Pole, by South Poles.

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* The crooked Magnets may be ſupported, by applying an Iron Wedge to their Poles; which method is extreamly eaſy and convenient, and is little, if at all, inferior to the other.

To make a bar magnetical, ſo that it ſhall have ſeveral Poles, ſupport it at the places, where the Poles are deſigned to be, with Poles of a contrary denomination from thoſe deſigned; and if any place is ſupported with South Poles, the next places on either ſide muſt be ſupported with North Poles, and contrariwiſe. Having done this, conſider each piece included between any two Sets of ſupporters, as a ſeparate bar, to be made Magnetical, with its South Pole towards the North Set of ſupporters, and its North Pole towards the South Set, and touch it accordingly. Magnets of this ſort with a great many Poles will not do well, unleſs they are very long; and at beſt they are always weak, and will very ſoon ſpoil themſelves; ſo that they ſhould only be made occaſionally.

In the following Table, the *firſt* Column has ſeveral lengths for bars, in feet and inches. The *ſecond*, ſhews the weights, in pounds and ounces Avoirdupois, that bars of ſuch lengths will bear. The *third* contains the number of ſix-inch bars proper to touch them with. And the *fourth*, the number of ſix-inch bars proper to ſupport them with at each end, which is made out according to the proportion of two ſupporters of it's own ſize at each end of the bar to be touched; but, as one is very little inferior to two, half the numbers here ſet down may, upon common occaſions, be ſufficient.

Feet.	Inch.	Pounds.	Ounces.	Touched by.	Supported by.
	† 1		0. $\frac{1}{64}$		
	† 2		0. $\frac{1}{10}$		
	3		0. $\frac{2}{7}$	2	1
	4		0. $\frac{3}{5}$	4	2
	5		1. $\frac{1}{13}$	6	2
	6		1. $\frac{3}{4}$	6	2
	8		4.	10	4
	10		7.	14	5
1	0		11.	18	6
1	6	2	0.	36	12
2	0	4	3.	56	19
2	6	7	8.	74	24
3	0	12	0.	96	32
4	0	25	0.	170	57
5	0	45	8.	246	82
6	0	73	0.	330	110

The above Table is made out in vulgar fractions, as being the moſt commonly known; and the numbers are not accurately true, according to the proportion they were calculated by, but as near the truth as conveniently might be expreſſed in the feweſt figures. The *weight*, recommended for different Magnets, is not in a cubical proportion of their lengths, (for the larger ones require a greater length in proportion than the ſmaller,) but in a proportion, the Index of which is 2. 63; and this was taken from the proportion of the Magnet of ſix inches long, to that of a foot and half, and the reſt were made out by analogy from them; and theſe ſeem to be not improper lengths for their bulk. But to determine this matter accurately, will require a long experience. The above lengths however will probably be found generally to anſwer pretty well, though they are not recommended as preciſely the beſt that can be. The *number* of ſix-inch bars, recommended for touching and ſupporting each Magnet, is (in round numbers) in proportion to the number of thoſe uſed for the ſix-inch bars, as the weight of a piece of Steel of ſix inches long, and of the thickneſs of ſuch Magnet, to the weight of one of the ſix-inch bars. But becauſe the number, here recommended for touching, may poſſibly be rather too great for the larger bars, (for the reſiſtance of the Steel, as it ſhould ſeem, is not ſo great, in proportion to the *contrary* Endeavour, in touching the larger ones, as the ſmaller,) it may not be amiſs (if this ſhould be found to be the caſe,) to touch them with ſomewhat fewer, till that number is diſcovered, with which they ſucceed the beſt.

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† Theſe muſt be touched by two ſix-inch bars, after the manner deſcribed in Pages 33 and 34, and need not be ſupported at all.

The number of bars, employed as ſecondary ſupporters to the firſt Set of ſupporters, ſhould not be fewer than one half, or at leaſt one third of the firſt Set: and theſe again ſhould be ſupported by half, or at leaſt one third of their own number, and ſo on, till they finiſh at laſt with one.

If any Perſon chuſes to make uſe of other ſized bars, inſtead of thoſe of ſix inches, either to touch or ſupport with, the number of them muſt be ſuch, that the whole ſurface of their ends, may be equal to that of the ſix-inch bars required for the ſame buſineſs.

The crooked Magnets of all ſorts may be of the ſame length, in proportion to their weight, as the ſtrait ones, and they may be touched and ſupported by the ſame number of bars.

For thoſe, who have only one or two Magnetical bars, and not Sets, with which they may retouch them upon occaſion, it will be very proper to obſerve the following directions, in order to preſerve them, as near as may be, in their full vigour.

A crooked Magnet of any ſort may have a wedge of Iron applied to both Poles; or, if there are two of them, that have their Poles equally diſtant from one another, they may be placed with their Poles of contrary denominations together; but they muſt never be ſuffered to touch one another any where, but at the Poles.

One ſtrait Magnet ſhould always be kept with its South Pole towards the North, or in the * Northern Magnetic hemiſphere downward, and in the Southern upward. Two ſtrait Magnets may be laid parallel to one another with their Poles of the ſame denomination contrary ways, having them connected by pieces of Iron paſſing croſs their ends; but they ſhould never be ſuffered to touch, except when they lye in the ſame line, and with Poles of contrary denominations.

A ſtrait Magnet ſhould never lift any Iron, *&c.* but by its South Pole in this Northern Magnetic hemiſphere, and by its North Pole in the Southern Magnetic hemiſphere; nor ſhould it be lifted by any Iron, *&c.* but by the contrary Poles; and no Iron ſhould be ſuffered to touch it any where, but at the ends.

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* By the Northern Magnetic hemiſphere is meant all that part of the World, where the South Pole of a Needle dips; and by the Southern, all that part where the North Pole dips.

A Method of obtaining Magnetiſm by Means of three Iron bars.

I Procured half a dozen ſmall bars of *Steel*, which were cleaned up, but not hardened, weighing all together one Ounce: They were two inches and a half long, and a quarter of an inch broad, and were marked at one end, as the ſix-inch bars. One of theſe was placed nearly in the direction of the Needle, with the marked end (which it was propoſed to make a South Pole,) towards the North: At each end of this was placed a large bar of *Iron*, in the ſame direction, and nearly horizontally, the North end being a little depreſſed: The bar of Iron at the North end was four feet long, and weighed thirty Pounds; and that at the South end was four feet and a half long, and weighed eighteen Pounds. This being done, an Iron Poker, weighing a little more than a Pound and ſix Ounces, was held nearly perpendicularly, the upper end inclining a little towards the South; the lower end of this (which was filed bright, that it might conveniently touch,) was placed upon the North end of the little Steel bar (which was to be the South Pole:) The Poker being thus placed, the little bar was ſtroked with it, from the North to the South end; where it was taken off, and brought back at a little diſtance; and being again placed as before, the little bar was ſtroked with it, in the ſame manner; and this was repeated twenty times, when it had acquired force enough to lift a ſmall key, weighing about an eighth part of an Ounce. After this, it was again ſtroked eighty times more, in the ſame manner as before; and then it would lift a key weighing a quarter of an Ounce. It was now laid by, and three more of the Steel bars were made Magnetical after the ſame manner. Of the two remaining, one was placed between the two Iron bars, as before; but, inſtead of the Poker, (which was now laid aſide,) it was touched by the four bars (already made in ſome degree Magnetical,) after the manner directed for making of Magnets; the two South Poles of the Touchers being kept at a little diſtance from the two North Poles, by a large Pin, which might be perhaps the thirtieth part of an inch in thickneſs: By this means the fifth bar acquired a good deal more power, than any of the four had. And the other remaining one being made Magnetical in the ſame way, theſe two were ſubſtituted inſtead of two of the four; and thoſe were touched in the ſame way, and ſubſtituted in the room of the remaining two of the four, which were touched likewiſe.

After this manner the whole ſix bars of Steel were all touched round, three or four times; the laſt touched being always ſubſtituted in the room of the weakeſt of the four employed in touching, till they had all received as much virtue, as in their ſoft ſtate they would retain; which was ſufficient to make them lift nearly an Ounce and quarter each, by one Pole.

By theſe ſix, thus made Magnetical, and ſeparated, as before, by a large Pin, a line of ſix-inch bars, that were hardened, was touched, according to the directions for making Magnets; and received by this means a power ſufficient to make each of them lift about two Ounces, by one Pole; which was abundantly ſufficient to make them communicate to others a ſtill greater power: For ſix others being touched by them, and they again by thoſe, and this being repeated two or three times, they acquired as great a power, as they would retain.

Though in the above proceſs ſix bars were found ſufficient, yet the greater eaſe, in performing the Operation with a larger number, makes it well worth while to uſe more. If half a dozen little bars are made Magnetical by means of the Iron bars only, and another half dozen are touched by them, and they again by the former, and ſo on, till the whole dozen are as Magnetical as they will be; and if then half a dozen ſix-inch bars are touched by the whole dozen of little ones, and theſe again are employed to touch another half dozen of ſix-inch bars, and in their turn are retouched by them, and ſo on, as before, till they have arrived at their utmoſt perfection, the whole Operation (with a convenient Apparatus,) may be eaſily performed in half an hour.

In order to obtain Magnetiſm, by means of Iron bars, with eaſe and certainty, the following cautions ſhould be obſerved.

Firſt. The Iron bars ſhould be large, and placed as nearly as may be in the direction of the Magnetic line, which is the beſt poſſible; however, if the Iron bars be large enough, the Experiment will ſucceed; though they ſhould lye in a direction varying many degrees from that, as was the caſe in the Operation related above, where the two larger bars varied about ſixty degrees from it.

Secondly. The Steel bars ſhould be ſmall, and ſoft; for otherwiſe they will not *eaſily* (and perhaps not at all) receive power enough to make them *communicate*, though they will always *receive* ſome.

With the Iron bars mention'd above I could not give power enough to the ſix-inch bars, though ſoft, to make them communicate. I tried with the ſame the ſmaller Steel bars alſo when in a hard ſtate, but neither to theſe could I communicate a ſufficient degree of virtue. I then tried the ſame, of a ſpring temper, and in about ſix hundred ſtrokes, they received about as much virtue, as the ſoft ones would do in twenty, and with ſome hundreds of ſtrokes more they would not receive any addition: they had however got power enough to communicate, and from theſe I made a Set of ſix-inch bars Magnetical, and improved them by one another, to their full perfection.

The Magnetic line, is that line a needle would place itſelf in, if left at entire liberty to turn itſelf as well vertically, as horizontally. Now all Iron not already *fixedly* magnetical, becomes magnetical immediately, when placed in a direction not too much differing from that Line; and moſt ſtrongly ſo, when in the direction of the Line itſelf: for this reaſon the Iron bars ſhould be placed, (as was ſaid before) as nearly as may be, in the direction of the Magnetic line; but becauſe this differs very much in different parts of the World, if it ſhould at any time happen that this ſhould not be known, and it ſhould yet be required to make Magnets, one or other of the following ways of placing the Iron bars will always ſucceed. Place them either *firſt*, horizontally from North to South; or *ſecondly*, horizontally from Eaſt to Weſt; or *thirdly*, perpendicularly; and let one end of the Poker or bar, with which the Steel bars are to be touched, be bent a little at one end, that it may come to bear, though the Poker be held nearly parallel to the other bars. This bent end of the Poker being placed upon *either* end of the little Steel bar to be touched, and the Poker being held in a direction nearly parallel to it, and with its other end towards the Iron bar, that lyes at the *oppoſite* end of the little Steel bar from that, upon which the bent end is placed, ſtroke with it to the other end; and there taking it off, replace it, and ſtroke again ſeveral times, till the little Steel bar has received a ſufficient power.

Becauſe Iron bars may ſometimes have acquired a ſmall degree of fixed Magnetiſm, by ſtanding long in one poſition, (though this does not often happen;) it may not be amiſs, when they are uſed, to retain the direction they have ſtood in, and to lay the ſame ends the ſame way, as much as may be, in their proper poſition; or elſe to give them, after they are placed in their proper poſition, a few good ſtrokes endways with a pretty heavy hammer; or they may be heated red hot, and laid to cool in that poſition; which will be the moſt certain way of any, to have them Magnetical in the right direction.

Beſide the above manner, Magnetiſm may be obtained, in a ſmall degree, by filing, drilling, and hammering; all which depend upon the ſame principle as the foregoing, *viz.* the poſition of the bodies concerned, in or near the Magnetic line. By hammering, which is the beſt of the three, I have communicated a ſmall degree of Magnetiſm; and ſufficient, with good management to have proceeded with; but this way is ſlower, leſs certain, and gives not ſo great a power, as that I have already related.

Of improving Natural *Magnets*, &c.

IN giving Magnetiſm to any Subſtance, capable of receiving it; in changing its direction; or taking it away, and giving it in a contrary direction; the whole difficulty is to apply a ſufficient force, and in a proper direction. How this may be done in Steel bars, has been already ſhewn. To do it in the *Natural* Magnets, is ſomewhat more difficult, upon account of their great thickneſs, and ſmall length; and alſo upon account of a certain glaſſineſs of the ſubſtance, which makes the bars, uſed in touching them, not apply ſo cloſely, as they will to

Steel: This laſt circumſtance makes them alſo more ſubject to damage one another. Whoever therefore tries ſuch experiments with the Natural Magnets, muſt expect that the bars he employs will want retouching, after the operation.

If a Natural Magnet is to have its power encreaſed, and it be a ſmall one, and ſhort; lay a great number of bars at its * ends, after the manner of ſupporters; and this will be ſufficient: If it be pretty long, ſo as to allow room for it, touch it alſo *double* with ſeveral bars (according to its bulk,) applying them to all ſides at once. If it is to have its Poles changed, lay the ſupporters ſo, that the centre of their force ſhall, at each end, lye at the end of the line deſigned to be the Axis of the Magnet; and touch it *double*, as near as may be in that direction. If the Poles are to be converted, and the Magnet be long enough, touch it *double* according to the directions for converting the Poles of an Artificial Magnet; then ſupport it, and touch it over again with freſh Touchers: Or if the Magnet is ſhort, apply bars as ſupporters only, and change them two or three times; or elſe make uſe of the method deſcribed below.

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* There are no directions here given, for applying the proper Poles, and for ſome other ſuch like circumſtances; which, it is preſumed, the Reader will be able eaſily to ſupply from what has been ſaid before.

As I have not had a ſufficient Apparatus, or Opportunities of trying experiments upon the larger Magnets, I can only recommend the following, as what ſeems, (to judge from analogy,) the moſt convenient way of managing them, and moſt likely to be attended with ſucceſs.

To encreaſe the power of a large Magnet, inſtead of placing ſupporters, put a large piece of Iron, the thickneſs and breadth of the Magnet, at each end of it. This piece of Iron ſhould be, either three or four times as long, as it is thick; or elſe ſhort, and three or four times as large at the end not touching the Magnet, as at the other: In the former of theſe ways there are to be placed on one *ſide*, in the other caſe, at the broad *end*, as many ſupporters as can conveniently ſtand there: This, if the Magnet be very ſhort, may be ſufficient; if it be long, it ſhould be touched *double* beſides. If the Poles of ſuch a Magnet are to be changed, the middle of the end of the piece of Iron placed at each end of the Magnet, is to be placed againſt the end of the line deſigned to be the Axis. If the Poles are to be converted, it ſhould be done firſt by touching *double*, if a ſufficient force of Magnetical bars can be applied for this purpoſe;

(for, as a great number of them are extremely ſubject to injure one another, this is ſomewhat difficult to do:) After the Poles are once converted, its power may be encreaſed as above. But if by touching *double*, the Poles will not be converted, place the Magnet between two pieces of Iron as before; then keeping them ſteady at their diſtance, remove the Magnet; and connecting the pieces of Iron by wedges of Iron, that may not ſtand in the way of it, when it is to be put in its place again, apply the ſupporters as before, and putting the Magnet in its place take off the Iron wedges. This may be done two or three times, if it be found neceſſary, retouching the ſupporters every time.

If the Magnets to be improved, *&c.* as above, be very ſuſceptible of Magnetiſm, they ſhould have much thicker Armour, than is generally uſed; (for they will retain much more Magnetiſm for it;) and the Armour ſhould be ſo faſtened, that the hoops, *&c.* uſed for that purpoſe, may not ſtand in the way of applying any thing to the ends, or the ſides; for it is much the beſt way to make any ſhort Magnets Magnetical in their Armour, becauſe they will retain more power for it.

But probably the beſt way of managing very large Magnets, would be to ſlit them into ſeveral long bars the length of the Stone; and having made them Magnetical ſingly, to put them into their Armour, according to the directions below for *Compound* Magnets.

Of Armed Artificial *Magnets.*

THE long ſtrait bars may be armed, and if they are large, they will ſometimes lift a larger piece of Iron on that account; but they will not lift ſo many Steel-filings, or touch Needles ſo well.

The crooked bars may be armed; and, becauſe their Poles will be near together, they will be convenient for lifting by a wedge of Iron. Thoſe bars of this ſort, that are to be armed, ſhould not be pointed at the ends, but left of the ſame breadth there with the reſt of the bar. The *Annular* Magnet is one of the moſt convenient forms for this purpoſe.

Short Steel bars may be armed and made Magnetical, in imitation of the *natural* Magnets. Theſe ſhould be made Magnetical after they are armed, and ſhould have pretty thick Armour. They may be managed after the method for improving ſmall Natural Magnets. Theſe may be made much ſuperior to the generality of *Natural* Magnets, and equal to the following *Compound Artificial* Magnets; and that with much leſs labour and expence, unleſs they are very large.

Armed *Compound Artificial* Magnets may be made of ſeveral bars exactly of a length, with Armour nicely fitted to them. The bars ſhould have the ſame proportions, as ſingle unarmed Magnets: They ſhould be touched ſingly, and put into their Armour, as they are touched, with the Poles of the ſame denomination the ſame way. The Armour ſhould be pretty thick, and ſhould have a wedge of Iron applied to it, whilſt the bars are putting in, and till the whole is bound together and finiſhed; for which reaſon the cap, that keeps the Armour together at bottom, ſhould be put on before any of the bars are put in. The Iron wedge ſhould always continue applied to the Magnet, but when it is uſed; for this will be a great preſervation to it; though, with all this precaution, it will loſe a great deal of its firſt ſtrength, in a very little time.

An occaſional Magnet of the ſame kind, and, on many accounts, preferable to the foregoing, may be thus made: Let there be a ſmall Box made, whoſe dimenſions in the inſide may be, about an inch deep, ſix inches long, and three or four wide: in the bottom of this Box muſt be fixed two bars of Iron, at each end one, about three eighths of an inch ſquare, which muſt reach quite croſs the ends, and through one ſide, (where there muſt be holes to let them paſs,) and project a little way beyond: theſe ends that project are to ſerve by way of feet to lift with, *&c.* like the feet of a common armed Natural Magnet: the faces of theſe feet ſhould lye in the ſame plain with each other; and they may be reduced, by taking off the edges, to about half the breadth of the bar, the flat way of the Box. When the Magnet is wanted, apply a wedge of Iron to the two feet, that come through the ſide of the Box; and having made any number of the ſix-inch bars as Magnetical as may be, place them one by one with their edges againſt the two Iron bars in the Box, and with their Poles of the ſame denomination the ſame way, puſhing them cloſe againſt the ſide of the Box, which will keep them from turning over and lying flat ways. Having placed as many of the ſix-inch Magnetical bars as are required, in this manner, lay two or three doubles of Flannel, or ſomething elſe that is ſoft and ſpringy, over them, and preſs them againſt the two Iron bars with the lid of the Box, and faſten it down. Such a Magnet as this may be eaſily taken to pieces and retouched, and ſet together again, as occaſion ſhall ſerve. There will be no occaſion for any great accuracy in the two Iron bars, (excepting their ends;) nor in the ſix-inch bars, in making them exactly of a length, *&c.* and they will ſerve for other uſes, when not wanted for this. I have known a Magnet of this kind, conſiſting of three dozen of ſix-inch bars, lift 50 pound Avoirdupois.

Of Bodies ſuſceptible *of Magnetiſm.*

THESE are probably no others than Iron in ſome ſhape or other, or bodies that have a mixture of Iron in them.

Amongſt theſe are, in the *firſt* place, Iron and Steel.

Secondly, Almoſt all ſorts of Iron Ore after Ignition, and ſome before; amongſt which is the *Natural* Magnet, and ſeveral ſorts of heavy, ſhining, opake, black, or dark Chocolate-coloured Sand, moſt if not all of which are Iron Ores. Sands of this ſort, that are black, are found in *Portugal*, *Italy*, *Virginia*, *China*, &c. There is a dark Chocolate-coloured Sand too, which comes from *China*, very near akin to the black ſort. The dark brown Sand amongſt Emery is of the ſame kind; indeed the Emery itſelf is often, and not very improperly called an Iron Ore, though the part that is hardeſt, and principally uſeful in grinding, *&c.* ſeems rather to be a kind of *Spar* belonging to the Ore, than the *Ore* itſelf: but if this be the caſe, they are ſo minutely mixed, that it is impoſſible entirely to ſeparate them. I have however found that part of the browner ſort of Emery, which adheres to the Magnet, much more friable than the reſt, opake, and nearly black; the other part being of a much lighter colour, and a great deal of it tranſparent. Amongſt the blacker ſort of Emery, there is but little tranſparent; and that, which adheres to the Magnet, differs very little either in hardneſs or colour from the reſt.

Thirdly, Amongſt Bodies ſuſceptible of Magnetiſm may be reckoned moſt Braſs, and ſometimes perhaps other Metals; and particular Bricks, that have been a good deal burnt in the fire. The Magnetiſm of theſe is owing, in all likelihood, to a ſmall quantity of Iron mixed with them. What is in the Braſs may come from the *Lapis Calaminaris*, which is ſaid to have often a ſmall mixture of Iron in it. The like is obſerved of moſt ſorts of Clay, eſpecially the red ſorts; and this may account for it in Bricks.

Of Artificial *Magnets made of* Iron Ores, *&c.*

ARtificial Magnets may be made of any ſort of Iron Ore, that is ſuſceptible of Magnetiſm. The Iron Ore *Stones* may be ſawed into *long Slips*, to make Magnets, in imitation of the unarmed Steel bars; or into *ſhorter pieces*, in imitation of the natural Magnets. The Iron Ore *Sands* may be fixed by ſome cement, and being formed into a proper ſhape, may be made Magnetical. In doing this, as little cement as poſſible ſhould be uſed, and ſuch Sand, as is moſt retentive of the Magnetic Power, ſhould be preferred; the Sand from Emery is pretty good for this purpoſe. Add to theſe, the *Scales* of Iron or Steel.

Hints *towards the* improving *of Magnets.*

PRobably the Natural Magnets, that are very thick in proportion to their length, if properly cut, would make two or three Magnets able to *lift* more, and a great many better for *touching*, than the entire one. They ſhould be cut parallel to the Axis; and ſome pieces may often be choſen, which are better than the reſt; and this ſhould be attended to, before the Stone is cut, that they may be as much as poſſible cut out by themſelves, and not mixed with the parts that are worſe.

Poſſibly ſome ſorts of Iron Ore either ignited or otherwiſe, may be found more tenacious of Magnetiſm, than Steel. Such (if they be found) cut into long ſlips, of a due proportion, muſt make better Magnets than Steel, and conſequently better *Needles* too. The beſt Natural Magnets may perhaps be ſuch.

Poſſibly too ſome ſorts of Iron Ore, that are very rigid, may not be capable of being made Magnetical, (by any force we can apply,) but in very ſmall particles, as in ſand or duſt; and perhaps ſome that will not become Magnetical even in this form, either *before* or *after* Ignition, may yet be capable of becoming ſo *whilſt* intenſely heated. Theſe probably (if there are any ſuch,) would at leaſt be extremely retentive of their Magnetiſm; and therefore Magnets made of ſuch, after the manner above mentioned for making Magnets of Magnetical Sands, (only that they muſt be made whilſt the cement is hot, that the little Sands may be at liberty to diſpoſe themſelves according to order,) would be hardly liable to be impaired by time, &c.

It has been already hinted, that poſſibly Steel may be rendered more tenacious of the Magnetic power, by Linſeed Oil; it may not therefore be amiſs perhaps to try Steel bars (properly hardened) that have been a long time laid in that, or ſome other Oil, which poſſibly may do as well.

And perhaps it may be better ſtill, to make a piece of Steel more ſtrongly Magnetical than the common bars will continue to be, and to keep it in that ſtrongly Magnetical State, and to let it lye a long time in Oil. A Ring of Steel may be made very ſtrongly Magnetical, the Magnetiſm going round and returning into itſelf; and this will continue in a ſtrongly Magnetical State, for the ſame reaſons that a magnet will always be more Magnetical towards the middle, than at the ends. The Ring, after it has lain, as long as required, in the Oil, may be cut into two *Semicircular* Magnets.

Some Uſes *of Magnets.*

BEſides the uſes of Magnets in touching Needles for the more important purpoſes of Navigation, *&c.* which have been already ſufficiently obſerved; it may not perhaps be amiſs juſt to mention two or three others, that have occurred, of leſs conſequence. They are theſe, which follow;

Firſt, Iron Ores may generally be diſcovered to be ſuch by the Magnet; for almoſt all of them (as was obſerved before) will be attracted by it, either before or after Ignition, (though ſome require an Ignition of ſeveral hours firſt.) A ſtrong Artificial Magnet well hung, and uſed as a Needle, (as being the moſt ſenſible to any ſmall attraction,) will beſt ſerve for this purpoſe.

Secondly, The Magnet will readily find, and ſeparate any little bits of Iron or Steel from other things, and particularly Iron or Steel Filings from thoſe of other Metals.

And *laſtly*, It will diſcover, whether Tools, *&c.* are made of Steel, or whether they are only Iron caſehardened; for the Steel will receive a ſtrong Touch, when the other will hardly receive any.

FINIS.

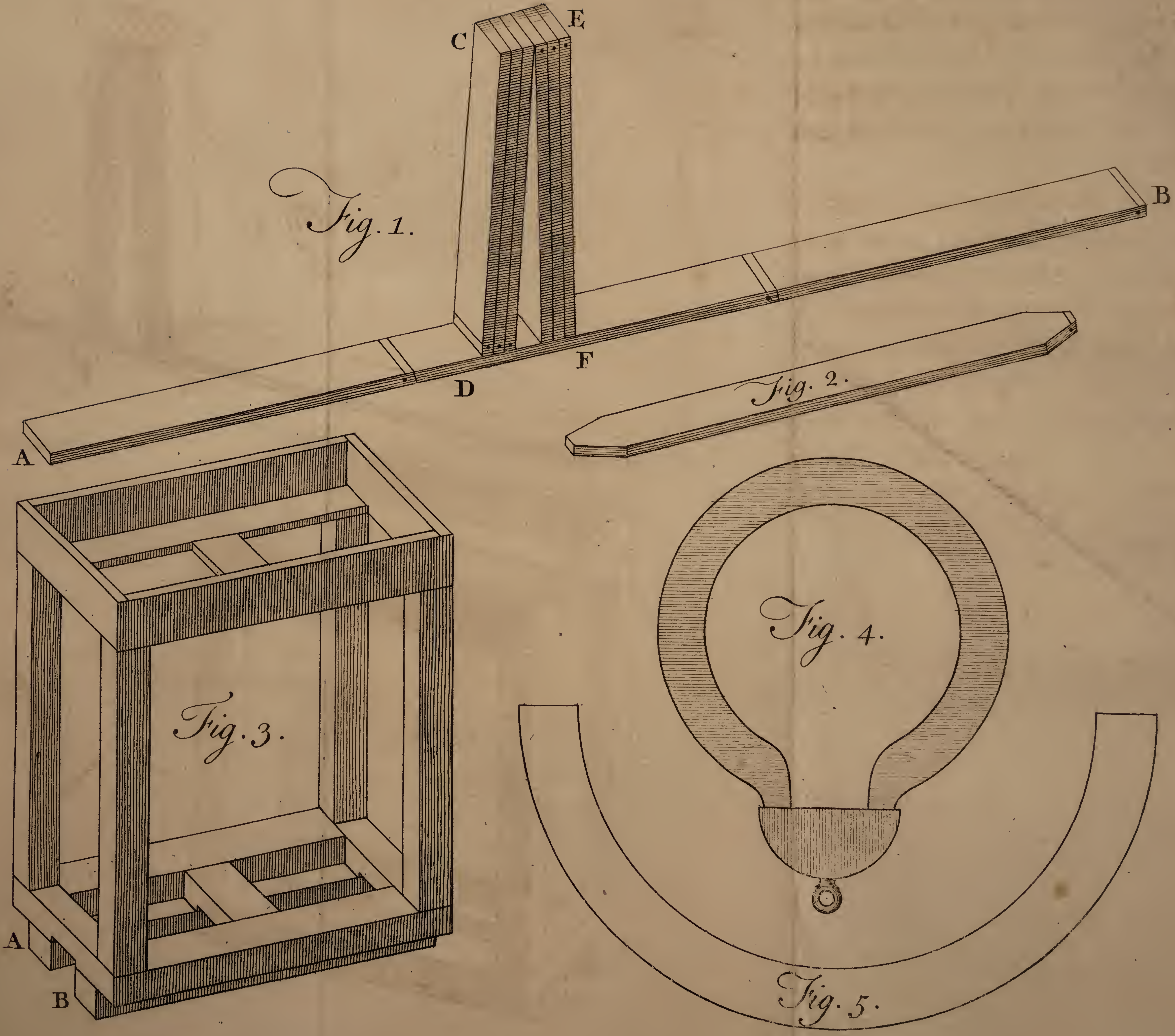
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Fig. 1.
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Fig. 4.
Fig. 5.